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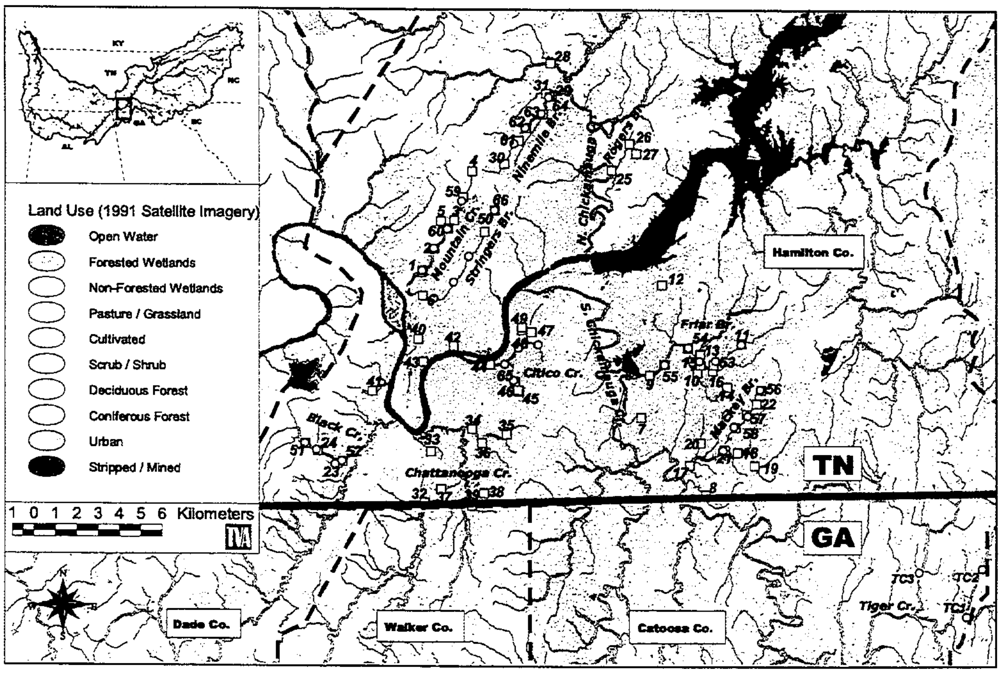
Assessment of Water Quality and Aquatic Macrofauna in Chattanooga Area Streams



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EXECUTIVE SUMMARY

Urbanization can negatively impact the hydrology, water quality, and biotic integrity of stream ecosystems. All too often, these impacts become economic burdens and serious threats to the health and well-being of communities. Urban stormwater is recognized as a major source of pollution (e.g., silt, metals, nutrients, pesticides, bacteria) to U.S. waterways. In 1987, Congress amended the Clean Water Act of 1987 to require National Pollutant Discharge Elimination System (NPDES) permits for stormwater discharges. The U.S. Environmental Protection Agency (USEPA) is implementing its stormwater program in two phases: Phase I requires NPDES permits for stormwater discharges associated with urban populations of 100,000 or greater, industrial activity, and construction sites over 5 acres; and Phase II requires permits for smaller municipalities and construction sites. The NPDES stormwater program requires the development and implementation of programs for monitoring water quality and aquatic life in local streams. Data gathered through such programs can be used to evaluate the impacts of various land-use practices and to implement possible mitigation activity in an effort to maintain healthy streams.

The University of Tennessee at Chattanooga (UTC), Department of Biological and Environmental Sciences, was contracted by the City of Chattanooga, Department of Public Works, Stormwater Management section, to collect baseline data on water quality and aquatic biota in Chattanooga area streams. Monitoring as part of UTC's "Urban Streams Project" will help the City of Chattanooga (population of 148,820) fulfill part of its NPDES permit requirements for stormwater discharge. We have expanded the scope of this project to create graduate research opportunities (thesis studies) for UTC students pursuing M.S. degrees in Environmental Science.

This project was designed to characterize water quality and aquatic macrofauna in Chattanooga area streams. Studies were conducted to evaluate: (1) water quality in relation to stormwater runoff; (2) macroinvertebrate assemblages and their relationships with water quality, habitat, and land-use variables; (3) fish assemblages and their relationships with water quality, habitat, and land-use variables; and (4) sampling techniques for assessing fish assemblages.

STUDY AREA

The study area included a total of 75 stream sites in the Nickajack Reservoir watershed (Tennessee River), located within the Chattanooga metropolitan area, Tennessee-Georgia. Seventy-two sites were located in stream systems of Hamilton County, Tennessee: Chattanooga Creek (8 sites), Citico Creek (10 sites), Lookout Creek (Black Creek, 4 sites), Mountain Creek (7 sites), North Chickamauga Creek (Falling Water Creek, 1 site; Ninemile Branch, 5 sites; Pitts Branch, 2 sites; Rogers Branch, 3 sites), South Chickamauga Creek (Friar Branch, 11 sites; Mackey Branch, 9 sites; unnamed tributaries, 2 sites), Stringers Branch (6 sites), and four unnamed tributaries to the Tennessee River (4 sites). Three sites were located in the Tiger Creek system, Catoosa County, Georgia.

All of the study sites were located in the Southern Limestone/Dolomite Valleys and Low Rolling Hills subdivision of the Ridge and Valley ecoregion. The median stream order was 3 (range, 1-5) and the drainage area was 5.6 km^2 (range, 0.1-156.4 km^2). Watershed land use was delineated from 1991 satellite imagery. Median land-use percentages (ranges in parentheses) were: forest, 46.7 % (9-97.6 %); agriculture, 24 % (2.4-63.9 %); and urban, 18 % (0-84 %).

Drought conditions prevailed during most of this study. Rainfall and runoff in the Tennessee Valley have been below average since July 1998.

EFFECTS OF STORMWATER RUNOFF ON STREAM WATER QUALITY

Water quality conditions (20 parameters) were assessed in base and storm flows at 66 stream sites in the winter-spring (January-May) and summer-fall (July-November), 1998-1999. Base-flow samples were collected following at least 72 hours of dry weather. Storm-flow samples were collected within the first 1-12 hours of a storm event ($\geq$ 0.25 cm of rain) following at least 72 hours of dry weather. Descriptive statistics are used to characterize overall water quality. Non-detectable values (at or below detection limit) are reported as minimum value estimates (mve; one-half of detection limit). Site-specific values for temperature, dissolved oxygen, pH, and "priority toxic" metals were compared to Tennessee's water quality standards (established for the protection of aquatic life). Also, sites exhibiting relatively high values ($\geq$ 95 percentiles) were noted for certain parameters (conductivity, suspended solids, metals, nutrients, and organic constituents). Wilcoxon tests were used to test for differences between base-flow and storm-flow conditions. Spearman's correlation analysis was used to examine relationships of suspended sediments with metals, nutrients, and organic constituents in storm flows; and relationships of conductivity with hardness and metals.

General Water Quality

Temperature.—Temperature (intensity of heat) affects the metabolism, behavior, and survival of individual organisms, and the productivity of ecosystems. Extremely high temperatures can be stressful/lethal for many aquatic organisms. Median water temperatures in base and storm flows averaged: 11.7 and 11.2°C, winter-spring; and 23.2 and 21.1°C, summer-fall. At 63 of the 66 sites, water temperatures were deemed adequate for warmwater fish and other aquatic organisms. However, summer-fall temperatures greater than 30.5°C (ranging from 31 to 34.6°C) violated the maximum temperature criterion. This violation was observed in base flows at three sites (unnamed tributaries) in the Citico Creek system.

Dissolved Oxygen.—Dissolved oxygen (DO), the concentration of free oxygen in water, is one of the most important environmental conditions affecting aquatic organisms. Median DO concentrations in base and storm flows averaged: 10.7 and 10.1 mg/L, winter-spring; and 7.7 and 6.5 mg/L, summer-fall. Modest storm-related declines in DO levels reflected increased levels of microbial decomposition and chemical oxidation in storm flows. On average, DO concentrations were adequate for fish and other aquatic life. However, the minimum DO criterion (<3-5 mg/L) was violated at 23 of the 66 study sites. DO concentrations less than 5 mg/L (ranging from 0.4 to 4.9 mg/L) were observed at one or more sites in the following stream systems: Chattanooga Creek (Dobbs Branch), Citico Creek (main stem, unnamed tributaries), South Chickamauga Creek (Friar Branch, Mackey Branch, unnamed tributaries), North Chickamauga Creek (Ninemile Branch, Rogers Branch), Stringers Branch, and two unnamed tributaries to the Tennessee River.

pH.—The pH (negative $\log_{10}$ of the hydrogen ion concentration) is a measure of the acidity and alkalinity of a solution. Median pH values in base and storm flows averaged: 7.7 and 7.4, winter-spring; and 7.8 and 7.6, summer-fall. Modest storm-related declines in pH may be attributable to acid precipitation and organic matter in surface runoff. At 60 of the 66 sites, pH conditions were adequate for fish and other aquatic life. Six of the 66 sites, however, violated Tennessee's aquatic life criterion for pH. Stream pH values outside of the 6.5-9.0 range (lower and upper pH ranges, 6.2-6.4 and 9.1-10.6) were observed at one or more sites in the following stream systems: Chattanooga Creek (Dobbs Branch, 1 site), Citico Creek (unnamed tributaries, 3 sites), and South Chickamauga Creek (Friar Branch, 2 sites).

Conductivity.—Specific conductance (conductivity) is an indirect measure of the concentration of ionized substances in water. Tennessee does not have an aquatic life criterion for conductivity. Median conductivity values in base and storm flows averaged: 299 and 193 μS/cm, winter-spring; and 338 and 259 μS/cm, summer-fall. Storm-related declines in conductivity values resulted from the dilution of mineral-rich base flows (supplied by groundwater) by the addition of mineral-poor rainwater. Conductivity was positively correlated with hardness, calcium and magnesium levels, but not with trace metals. Relatively high conductivity values ($\geq 95^{th}$ percentiles [range, 428-1133 μS/cm]) were observed at one or more sites in the following stream systems: Chattanooga Creek (main stem, Dobbs Branch, unnamed tributaries), Citico Creek (main stem, unnamed tributaries), South Chickamauga Creek (Friar Branch), and North Chickamauga Creek (Ninemile Branch), and one unnamed tributary to the Tennessee River.

Non-filterable Residue (NFR).—The NFR is a measure of the concentration of suspended solids in a water sample. Excess amounts of suspended solids can impact streams by reducing light penetration, altering stream flows, transporting toxicants, accelerating eutrophication, and smothering aquatic life. Tennessee does not have an aquatic life criterion for suspended solids. Median NFR concentrations in base and storm flows averaged: 2.0 and 30.3 mg/L, winter-spring; and 3.0 and 10.3 mg/L, summer-fall. Storm-related increases in the NFR resulted from runoff inputs of "new" suspended solids and/or the resuspension of "old" sediments. The concentration of suspended solids was positively correlated with metals, nutrients, and oxygen demands. Relatively high NFR levels ($\geq 95^{th}$ percentiles [range, 51-650 mg/L]) were observed at one or more sites in the following stream systems: Chattanooga Creek (main stem, Dobbs Branch, unnamed tributaries), Citico Creek (unnamed tributaries), Mountain Creek (main stem, unnamed tributary), North Chickamauga Creek (Ninemile Branch), South Chickamauga (Friar Branch, Mackey Branch), and two unnamed tributaries to the Tennessee River.

Hardness Properties

Hardness represents the total concentration of polyvalent cations expressed as their calcium carbonate equivalent. In most freshwater systems, calcium and magnesium are the principle cations contributing to hardness. Increased levels of calcium-magnesium hardness can reduce the toxicity of several metals. Tennessee does not have aquatic life criteria for hardness, calcium, and magnesium. Winter-spring medians in base and storm flows averaged: hardness, 143.8 and 98.1 mg/L; total calcium, 48.5 and 32.0 mg/L; and total magnesium, 5.7 and 3.9 mg/L. Summer-fall medians in base and storm flows averaged: hardness, 161.7 and 131.5 mg/L; total calcium, 55.3 and 44.3 mg/L; and total magnesium, 6.7 and 4.9 mg/L. Storm-related declines in hardness, calcium, and magnesium levels resulted from the dilution of mineral-rich base flows by the addition of mineral-poor rainwater. Moderately hard or hard waters (hardness, 75-150 mg/L or >150 mg/L) were observed in base flows at 62 of the 66 sites.

Trace Metals

Trace metals occur in relatively low concentrations in most unpolluted waterways. Increased levels of trace metals are potentially toxic to aquatic life. We used Tennessee's criterion maximum concentrations (CMCs were hardness-dependent values) to evaluate site-specific levels of zinc, lead, and copper ("priority toxic" metals). Tennessee does not have aquatic life criteria for aluminum, iron, and manganese (other metals assessed in this study). Storm-related increases in concentrations of five metals can be attributed to metals from runoff and/or resuspended sediments. Positive correlations of the NFR with five metals in storm flows indicate that a significant portion of the metal load was associated with suspended solids.

Total Aluminum (Al).—Median aluminum levels in base and storm flows averaged: 160 and 2100 µg/L, winter-spring; and 130 and 475 µg/L, summer-fall. Relatively high aluminum levels (≥ 95th percentiles [range, 3200-14000 µg/L]) were observed at one or more sites in the following stream systems: Chattanooga Creek (unnamed tributary), Citico Creek (unnamed tributaries), Lookout Creek (Black Creek), Mountain Creek (main stem, unnamed tributary), North Chickamauga Creek (Ninemile Branch), South Chickamauga Creek (Friar Branch, Mackey Branch, unnamed tributary), and two unnamed tributaries to the Tennessee River.

Total Iron (Fe).—Median iron concentrations in base and storm flows averaged: 225 and 1950 µg/L, winter-spring; and 195 and 775 µg/L, summer-fall. Relatively high iron levels (≥ 95th percentiles [range, 4700-18000 µg/L]) were observed at one or more sites in the following stream systems: Chattanooga Creek (unnamed tributary), Citico Creek (unnamed tributary), Lookout Creek (Black Creek), Mountain Creek (main stem, unnamed tributary), North Chickamauga Creek (Ninemile Branch), South Chickamauga Creek (Friar Branch, Mackey Branch, unnamed tributary), and two unnamed tributaries to the Tennessee River.

Total Manganese (Mn).—Median manganese concentrations in base and storm flows averaged: 29 and 68 µg/L, winter-spring; and 47 and 70 µg/L, summer-fall. Relatively high manganese levels (≥ 95th percentiles [range, 340-3500 µg/L]) were observed at one or more sites in the following stream systems: Chattanooga Creek (unnamed tributary), Citico Creek (unnamed tributary), Mountain Creek (main stem), North Chickamauga Creek (Ninemile Branch), South Chickamauga Creek (Friar Branch, unnamed tributary), and one unnamed tributary to the Tennessee River.

Total Zinc (Zn).—Median zinc concentrations in base and storm flows averaged: 5 (mve) and 15 µg/L, winter-spring; and 5 and 18 µg/L, summer-fall. Relatively high zinc levels (≥ 95th percentiles [range, 70-1400 µg/L]) were observed at one or more sites in the following stream systems: Chattanooga Creek (Dobbs Branch, unnamed tributaries), Citico Creek (unnamed tributary), Mountain Creek (main stem), North Chickamauga Creek (Pitts Branch, Rogers Branch), South Chickamauga Creek (Friar Branch), and two unnamed tributaries to the Tennessee River. At 10 of the 66 sites, zinc levels exceeded the aquatic life CMC. This violation occurred at one or more sites in the Chattanooga Creek (3 sites), Citico Creek (1 site), Mountain Creek (1 site), and Friar Branch (3 sites) systems, and in two unnamed tributaries to the Tennessee River (2 sites).

Total Lead (Pb).—Median lead concentrations in base and storm flows averaged: 0.5 (mve) and 2.5 µg/L, winter-spring; and 0.5 and 1.3 µg/L, summer-fall. Relatively high lead concentrations (≥ 95th percentiles [range, 5-38 µg/L]) were observed at one or more sites in the following stream systems: Chattanooga Creek (Dobbs Branch, unnamed tributary), Citico Creek (unnamed tributaries), South Chickamauga Creek (Friar Branch), and three unnamed tributaries to the Tennessee River. In all cases, lead concentrations were below the aquatic life CMC; however, it was very close at one site in the Friar Branch system (main stem).

Total Copper (Cu).—The median copper concentration was 5 µg/L (mve), regardless of the year, season, or flow condition. Copper concentrations were non-detectable at 65 of the 66 sites. However, at one site in the Chattanooga Creek system (unnamed tributary), the copper concentration exceeded the aquatic life CMC (50 µg/L).

Inorganic Nutrients

Inorganic nutrients are required by aquatic organisms for normal growth and activity. Excessive amounts of nutrients – mainly nitrogen and phosphorus -- can result in over-stimulation of biological production and related water quality problems (e.g., eutrophication).

Elevated levels of certain nutrients (e.g., unionized ammonia, nitrite-nitrate) can be toxic to aquatic life. The State of Tennessee does not have aquatic life standards for nitrogen and phosphorus. However, the Tennessee Department of Environment and Conservation is developing ecoregion-specific criteria for nitrite-nitrate and phosphorus.

Ammonia (NH_3 & NH_4^+).--Median ammonia concentrations in base and storm flows averaged: 0.005 (mve) and 0.03 mg/L, winter-spring; and 0.013 and 0.023 mg/L, summer-fall. Higher ammonia levels in storm flows reflect significant concentrations in runoff and/or resuspended sediments. Ammonia was positively correlated with NFR in storm flows, which suggests that a significant portion of the ammonia load was associated with suspended solids. Relatively high ammonia concentrations ($\geq$ 95th percentiles [range, 0.19-14 mg/L]) were observed at one or more sites in the following stream systems: Chattanooga Creek (Dobbs Branch, unnamed tributary), Citico Creek, North Chickamauga Creek (Ninemile Branch), and South Chickamauga Creek (Friar Branch), and three unnamed tributaries to the Tennessee River. Ammonia toxicity problems (assessed using USEPA's pH-dependent CMC) were not detected at any sites.

Nitrite-nitrate (NO_2^- & NO_3^-).--Median nitrite-nitrate concentrations in base and storm flows averaged: 0.783 and 0.498 mg/L, winter-spring; and 0.403 and 0.55 mg/L, summer-fall. Nitrite-nitrate levels were higher in base flows in the winter-spring of 1998-1999, but were higher in storm flows in the summer-fall of 1998. In 1999 storm flows, nitrite-nitrate was negatively correlated with the NFR in the winter-spring, but was positively correlated in the summer-fall. Higher nitrite-nitrate levels in base flows reflect relatively high concentrations of nitrate in the groundwater. Conversely, higher nitrite-nitrate levels in storm flows reflect significant amounts in runoff and/or resuspended sediments. Relatively high nitrite-nitrate concentrations ($\geq 95^{th}$ percentiles [range, 1.3-3.1 mg/L]) were observed in at one or more sites in the following stream systems: Chattanooga Creek (Dobbs Branch, unnamed tributaries), Citico Creek, Mountain Creek, North Chickamauga Creek (Ninemile Branch, Rogers Branch), South Chickamauga Creek (Friar Branch, Mackey Branch), and Stringers Branch, and one unnamed tributary to the Tennessee River. Most study sites exhibited higher nitrite-nitrate levels than those reported in Tennessee's Ridge and Valley reference streams.

Total Phosphorus (P).—Median phosphorus concentrations in base and storm flows averaged: 0.23 and 0.93 mg/L, winter-spring; and 0.025 and 0.095 mg/L, summer-fall. Higher phosphorus levels in storm flows reflect significant concentrations in runoff and/or resuspended sediments. Positive correlations of phosphorus with the NFR in storm flows suggest that a significant portion of the phosphorus load was associated with suspended solids. Relatively high phosphorus concentrations ($\geq$ 95th percentiles [range, 0.18-1.60 mg/l]) were observed at one or more sites in the following stream systems: Chattanooga Creek (Dobbs Branch, unnamed tributaries), Citico Creek (unnamed tributaries), Mountain Creek, North Chickamauga Creek (Ninemile Branch), and South Chickamauga Creek (Friar Branch, unnamed tributary), and two unnamed tributaries to the Tennessee River. Most study sites exhibited higher phosphorus levels than those reported in Tennessee's Ridge and Valley reference streams.

Aggregate Organic Constituents

Organic (carbonaceous) compounds are produced by organisms or synthetic processes. Because most organic compounds are quickly oxidized by microorganisms -- creating an oxygen demand -- high concentrations of organic constituents can lead to dissolved oxygen depletions.

Biochemical Oxygen Demand (BOD).—The BOD of water is the a measure of the amount of oxygen required for the oxidative decomposition of oxidizable material (mostly organic compounds) by microorganisms. Median BOD values in base and storm flows averaged: 1.0

(mve) and 1.0 mg/L, winter-spring; and 1.0 and 2.0 mg/L, summer-fall. Most BOD values were non-detectable or very close to the detection limit. Relatively high BOD values ($\geq$ 95th percentiles [range, 5 - 38 mg/L]) were observed at one or more sites in the following stream systems: Chattanooga Creek (Dobbs Branch, unnamed tributary), Citico Creek, North Chickamauga Creek (Ninemile Branch, Rogers Branch), and South Chickamauga Creek (Friar Branch, unnamed tributary), and two unnamed tributaries to the Tennessee River.

Chemical Oxygen Demand (COD).—The COD measures the quantity of a strong oxidizing agent required to oxidize all oxidizable substances (including those that cannot be oxidized by microbes) in a water sample. The COD test estimates the "maximum possible" (though not probable) oxygen demand. Median COD values in base and storm flows averaged: 4.8 and 15.0 mg/L, winter-spring; and 4.3 and 21.3 mg/L, summer-fall. Higher COD values in storm flows reflect significant concentrations of oxygen-depleting substances (organic and inorganic oxidants) in runoff and/or resuspended sediments. The COD was positively correlated with NFR in storm flows, suggesting that a significant amount of oxidizable matter was associated with suspended solids. Relatively high COD values ($\geq$ 95th percentiles [range, 26-180 mg/L]) were observed at one or more sites in the following stream systems: Chattanooga Creek (Dobbs Branch, unnamed tributaries), Citico Creek, North Chickamauga Creek (Ninemile Branch, Rogers Branch), and South Chickamauga Creek (Friar Branch, unnamed tributary), and two unnamed tributaries to the Tennessee River.

Oil and Grease.— Oil/grease is defined as any material recovered as a substance soluble in an organic-extracting solvent. Median oil/grease concentrations averaged 2.5 μg/L (mve), regardless of the year or season. Oil/grease was detected in only two samples (range, 6-7 mg/L) collected from two sites in the Chattanooga Creek system (unnamed tributaries).

BENTHIC MACROINVERTEBRATE ASSEMBLAGES

Benthic macroinvertebrate assemblages were sampled at a total of 31 sites in Chattanooga area (Tennessee-Georgia) stream systems (3-5 sites per stream system). Invertebrate sampling was conducted using a variety of methods in representative habitats at 20 sites in May-June, 1998; 2 sites in July-August, 1998; 21 sites in May-July, 1999; and 2 sites in August, 1999. Collective sampling efforts yielded a total of 81 families of invertebrates.

EPT Taxa Richness

The EPT taxa richness index is defined as the total number of different families in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). These three orders are widely accepted as groups whose taxa are considered pollution intolerant. Their presence indicates water quality and habitat features meet the minimum criteria to support these sensitive taxa. The number of EPT taxa decreases with increasing levels of environmental degradation. The Tennessee Valley Authority (TVA) has established a rating system for Ridge and Valley streams based on the number of families of EPT collected with a standardized effort. The rating designations and number of EPT families (scores given in parentheses) necessary are: "poor" (0-4); "poor/fair" (5-6), "fair" (7-11), "fair/good" (12), and "good" (13+).

Median EPT taxa richness (scores in parentheses) indicated that stream health rated "poor/fair" in both 1998 (6.5) and 1999 (5). Stream-specific assessments yielded the following EPT ratings (ranges of scores in parentheses): Citico Creek, "poor" (0-1); Lookout Creek - Black Creek, "fair" to "good" (7-16); Mountain Creek, "poor" to "fair" (1-11); North Chickamauga Creek - Ninemile Branch, "poor" to "fair" (3-9); South Chickamauga Creek - Friar Branch, "poor" to "poor/fair" (4-6), Mackey Branch, "poor/fair" to "fair" (5-9), and Tiger Creek, "fair" to "good" (8-13); and Stringers Branch, "poor" (0-1).

EFFECTS OF WATERSHED LAND USE ON BENTHIC MACROINVERTEBRATE ASSEMBLAGES

Stream-dwelling invertebrates are well suited as indicators of water and habitat quality and ecosystem degradation, and often reflect land-use activities in the watershed. Benthic macroinvertebrate assemblages, water quality, habitat conditions, and watershed land-use features were sampled at 20 sites in five Ridge and Valley streams in Hamilton County, Tennessee, May-June 1998. The study sites were located on second- to fourth-order streams with drainage areas of 3.8 to 46.9 km^2. Watershed land uses varied from 0 % to 26.9 % urban, 19.1 % to 29.3 % agricultural, and 45.3 % to 81.0 % forested.

Qualitative sampling efforts yielded a total of 76 families of invertebrates from a variety of habitats. EPT taxa richness averaged 7.4 (standard deviation = 3.7) and ranged from 3 to 16 (corresponding to ratings of "poor" to "good," respectively) at the individual sites. This wide range of EPT taxa richness scores indicates that portions of the streams were severely degraded, while other portions were considered "healthy." Quantitative sampling yielded a total of 22,613 invertebrates in 79 Hess samples from riffle habitats; these data were assessed using selected biotic indices to evaluate water and/or habitat quality and anthropogenic disturbances. Significant differences were observed among sites within streams for EPT taxa richness, percent abundance of EPT, percent abundance of chironomids, and other biotic indices, and for habitat variables such as streambed substrate; these differences reflected varying levels of degradation among sites within streams. Less-disturbed sites were characterized by relatively high EPT scores (taxa richness and/or percent abundance), low percent abundance of chironomids, and high percentages of cobble substrate. Conversely, degraded sites were characterized by low EPT

scores, high percent abundance of chironomids, and sedimentation problems. Pockets of relatively undisturbed invertebrate assemblages (approaching "reference-site" quality) were located in the upper reaches of Black Creek, Mountain Creek, and Ninemile Branch at the time of this study; however, biotic assemblages and habitat conditions were more degraded in the lower reaches of these streams. Significant correlations observed in this study underscore the negative effects of agricultural and urban development on invertebrate assemblages and habitat structure in streams.

STREAM FISH ASSEMBLAGES

Fish assemblages were sampled at a total of 32 sites in Chattanooga area (Tennessee-Georgia) stream systems (3-5 sites per stream system). Electrofishing (backpack shocking) was conducted at 22 sites in May-June and July-August, 1998; 21 sites in May-July, 1999; and 2 sites in August, 1999. Collective sampling efforts yielded a total of 40 fish species representing nine families.

Index of Biotic Integrity

Karr's index of biotic integrity (IBI) was used to assess stream health at individual sites. The IBI is calculated from data collected on an entire fish assemblage at a site. Twelve metrics (fish assemblage attributes) are used to score/rate the site. Metrics examine species richness and composition, trophic composition, and abundance and condition. We used IBI metrics and scoring criteria standardized by TVA for use in Tennessee's Ridge and Valley streams. Stream sites are rated according to IBI scores as follows: 12-22, "very poor"; 28-34, "poor"; 40-44, "fair"; 48-52, "good"; and 58-60, "excellent." Ratings of "very poor/poor," "poor/fair," "fair/good," and "good/excellent" are given to sites whose scores fall between those listed above.

Median IBI scores (in parentheses) indicated that stream health rated "poor/fair" in 1998 (36) and "poor" in 1999 (34). Stream-specific assessments yielded the following IBI ratings (ranges of scores in parentheses): Citico Creek, "very poor" to "poor" (16-32); Lookout Creek - Black Creek, "poor" to "fair" (30-42); Mountain Creek, "very poor/poor" to "good" (26-48); North Chickamauga Creek - Ninemile Branch, "poor" to "poor/fair" (28-38); South Chickamauga Creek - Friar Branch, "very poor/poor" to "poor" (24-34), Mackey Branch, "very poor/poor" to "fair" (26-44), and Tiger Creek, "poor" to "fair/good" (32-46); and Stringers Branch, "very poor/poor" to "poor" (26-30).

EFFECTS OF LAND USE ON THE BIOTIC INTEGRITY OF FISH ASSEMBLAGES

Twenty-one sites across seven Ridge and Valley streams in the Chattanooga metropolitan area, Tennessee-Georgia, were studied, April-August, 1999. The study sites were located on second- to fifth-order streams with drainage areas of 3.8 to 46.9 km^2. Urban land use in the watersheds varied from 0 % to 78.8 %. Study sites were characterized in terms of water quality, habitat, and fish assemblages. Relationships among these features and land use, at both the riparian and watershed scales, were examined.

A total of 40 species representing nine families of fishes was collected by electrofishing. Biotic integrity at all sites was degraded to some extent, with 15 sites receiving IBI ratings of "poor" or lower. The IBI score was negatively correlated with urban land use (at the watershed scale) and positively correlated with habitat features (rocky substrate and thalweg depth). Correlations of the IBI with riparian land-use variables were not significant. Instream rocky substrate was correlated with land use at both the riparian and watershed scales (negatively correlated with urban land use and positively correlated with wooded/forested land use).

EVALUATION OF SAMPLING METHODOLOGIES FOR

ASSESSING FISH SPECIES RICHNESS

We evaluated the adequacy of different electrofishing approaches for estimating species richness in low-order Ridge and Valley streams. Our study objectives were to determine the effects of the sampling season, reach length, habitat sequences, and sampling intensity on estimates of fish species richness. Fish assemblages were sampled at 18 sites across five streams in Hamilton County, Tennessee, May-June (spring) and July-August (summer), 1998. Study sites were located on second- to fourth-order streams. At each site, fish were collected using one or two backpack electrofishers within habitat-specific enclosures. Reach lengths (sampling distance) ranged from 30 to 61 times the mean stream width (MSW) (103 to 278 m, respectively). The number of habitat sequences (contiguous riffle/run-pool units) varied from one to seven. Single-pass sampling (one collection per site) was conducted at all sites. Multiple-pass sampling (two and three collections per site) was conducted at selected sites.

Fish species richness averaged slightly higher in the spring (13.6) than summer (12.7). Spring and summer estimates were positively correlated; this indicates that the two sampling approaches provide similar trend data. Regression analysis revealed a positive asymptotic relationship between species richness and the reach length sampled. On average, sampling a reach length of 41 times the MSW yielded 90 % of the estimated maximum species richness. Given the high level of inter-site variation observed in the number of habitat sequences (ranging from 1 to 7 at the sites), we recommend using the reach length to standardize sampling effort. Estimates of species richness from single- and multiple-pass sampling were statistically similar. Our findings indicate that accurate estimates of species richness can be obtained by single-pass electrofishing in the spring or summer, and by sampling a reach length of 41 times the MSW.